Title: Ultra-processed foods and binge eating: A retrospective observational study

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Title: Ultra-processed foods and binge eating: A retrospective observational study

Running title: NOVA-4 foods and binge eating

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Abstract

OBJECTIVE

There is increasing evidence of the impact of ultra-processed foods on multiple metabolic and neurobiological pathways, including those involved in eating behaviours, both in animals and in humans. In this pilot study, we aimed to explore ultra-processed foods and their link with disordered eating in a clinical sample.

METHODS

This was a single site, retrospective observational study in a specialist eating disorder service using self report on the electronic health records. Patients with a DSM-5 diagnosis of anorexia nervosa (AN), bulimia nervosa (BN) or binge eating disorder (BED) were randomly selected from the service database in Oxford from 2017 to 2019. The recently introduced NOVA classification was used to determine the degree of industrial food processing in each patient's diet. Frequencies of ultra-processed foods were analysed for each diagnosis, at each mealtime and during episodes of bingeing.

RESULTS

71 female and 3 male patients were included in the study. 22 had AN, 25 BN and 26 had BED. Patients with AN reported consuming 55% NOVA-4 foods, as opposed to approximately 70% in BN and BED. Binge foods were 100% ultra-processed.

DISCUSSION

Further research into the metabolic and neurobiological effects of reducing ultra-processed food intake on bingeing behaviour is needed.

Key words: Anorexia nervosa, bulimia nervosa, binge eating disorder, ultra-processed food, metabolic and neurobiological effect.

NOVA-4 foods and binge eating

INTRODUCTION

There has been little research into the dietary intake of people with eating disorders, despite the clear relevance to the condition (Ayton & Ibrahim, 2019). The mainstream psychological therapies encourage the re-introduction of regular eating (NICE, 2017), and emphasize the importance of widening food choices according to individual preferences, including cultural beliefs; but they pay no attention to personal metabolic and neurobiological responses, and usually include ultra-processed foods (Hart, Marnane, McMaster, & Thomas, 2018).

In general, ultra-processed foods are high in sugars and fats and low in natural protein (Mendonca et al., 2016; Monteiro et al., 2018). The recently proposed NOVA classification system provides a framework for categorising the degree of modern industrial food processing(Monteiro et al., 2019). It comprises four groups:

- Group 1: unprocessed or minimally processed foods (e.g.: fruit, vegetables, meat, fish);
- Group 2: processed culinary ingredients used in home cooking, such as flour, olive oil, butter, cream, dried fruit, herbs;
- Group 3: processed foods, such as tinned food, cheeses, freshly made breads;
- Group 4: ultra-processed foods (e.g. soft drinks, sweet or savoury packaged snacks, reconstituted meat products, pre-prepared frozen dishes, diet products).

NOVA-4 definition includes: '*Ultra-processed foods, …, are not modified foods but formulations made mostly or entirely from substances* ***derived from foods*** *and additives and include other sources of energy and nutrients not normally used in culinary preparations. A multitude of sequences of processes is used to combine the usually many ingredients and to create the final product (hence 'ultra-processed').* (Monteiro et al., 2019). Many of these ingredients, including high level of sugars, are metabolically active (Lustig, 2017), and may have an addictive potential (Schulte, Potenza, & Gearhardt, 2017).

Studies based on the NOVA classification show exponential growth in the consumption of ultra-processed products and confirm that they have gradually been displacing unprocessed or minimally processed foods and freshly prepared meals (Freire et al., 2018). The recent U.K. National Diet and Nutrition Survey (NDNS) found that 56.8% of foods (ranging from 30 to almost 80%) consumed in the UK are ultra-processed, and in parallel, the dietary intake of carbohydrates, free sugars, total fats increased significantly while the consumption of protein decreased (Rauber et al., 2018). Ecological and epidemiological studies have shown a link between the consumption of NOVA-4 foods and increased rates of obesity and metabolic disorders (Juul, Martinez-Steele, Parekh, Monteiro, & Chang, 2018; Nardocci et al., 2019; Wang et al., 2017), indicating that they may reduce satiety and stimulate overeating (Fardet, Mejean, Laboure, Andreeva, & Feron, 2017; Juul et al., 2018; Monteiro et al., 2019; Nardocci et al., 2019). A recent, carefully controlled randomized trial comparing ad libitum ultra-processed with unprocessed diets found that people on ultra-processed foods consumed 500 kcal/day more calories, with increased consumption of carbohydrate and fat but not protein (K. D. Hall et al., 2019), associated with widespread endocrine changes. This finding was also consistent with recent evidence, from both animal (Bortolin et al., 2018) and human experiments (Small & DiFeliceantonio, 2019), which showed that ultra-processed foods interact with various hormonal and neurobiological systems that affect food intake.

Recent metabolic research has also highlighted that responses to common foods vary from person to person, this being influenced by a number of factors, including insulin resistance,

sleep, stress, exercise and the microbiome (Zeevi et al., 2015). These differences are associated with impaired glucose tolerance and insulin sensitivity (H. Hall et al., 2018). The implications of this novel research have been largely unexplored in the eating disorder field, even though several studies have highlighted the metabolic underpinning of eating disorders, including insulin dysregulation (Duncan et al., 2017; Ilyas et al., 2018). In addition, several ingredients in ultra-processed foods impair the gut microbiome and intestinal permeability (Lerner & Matthias, 2015). This is relevant to patients with restricting eating disorders, who often use low fat products in an attempt to control their calorie intake, and experience abdominal complaints, which may drive further restriction (Halmos, Mack, & Gibson, 2019).

To our knowledge there have been no studies examining the links between NOVA-4 foods and eating disorders. Clinical experience suggests that patients do consume a high proportion of ultra-processed foods: these can be low calorie products (Schebendach et al., 2017), or as described in Fairburn's book 'Overcoming binge eating', binge foods, such as ice cream, doughnuts, cookies, etc. (Fairburn, 2013).

Objective: following our review of the relevant literature (Ayton & Ibrahim, 2019), this pilot study aimed to explore the degree of industrial processing in the food choices of patients with eating disorders. We hypothesised that ultra-processed food consumption may be associated with abnormal eating behaviours, such as bingeing.

METHOD:

This was a cross-sectional retrospective observational study using routinely collected data from the electronic health records in Cotswold House, Oxford, a specialist NHS eating disorder service for adults (over 18 years old). Patients with an ICD-10 diagnosis of anorexia nervosa, bulimia nervosa and binge eating disorders were randomly selected from the service database between 2017 and 2019. The service uses both ICD-10 and DSM-5 diagnostic criteria. A senior author (AA) checked the accuracy of the clinical diagnoses based on the assessment documentation, and for the purposes of this paper, we used DSM-5 diagnostic criteria. As part of the assessment, clinicians documented dietary intake by asking the patient to describe 'a typical food intake per day over the past two weeks', including specific mealtimes, bingeing and purging. To reduce recall bias we did not attempt to estimate total daily energy intake. Only the types and frequency of food choices, but not the amounts were included in the analysis. Subjective and objective binges were analysed together. The NOVA classification (Monteiro et al., 2018) was used to categorize the degree of industrial food processing in each patient's diet by two of the authors (JD & AA) independently. Foods were categorised into Nova 4 groups based on the patients' reports at each mealtimes. Differences in coding between the authors were resolved by joint discussion referring to the NOVA definitions (Monteiro et al., 2019). Patients with inadequate dietary information on their assessment were excluded from the study. We also reviewed the health records for evidence of glucose intolerance, as this is an important factor of individual metabolic response to foods, and is associated with binge eating disorder (Ilyas et al., 2018). The study was approved by Oxford Health Foundation Trust Audit Department. SPSS-22 was used for descriptive statistics and Pearson's s chi-square test was used to compare categorical variables.

RESULTS

Seventy-three patients were included from the original pool of 79 patient records. Three were male and 71 were female. Six were excluded owing to insufficient recording of dietary intake details during assessment by the clinician involved. Twenty-two patients had a DSM-5 diagnosis of anorexia nervosa (AN) (21 restrictive and 1 binge-purging subtype), 25 had bulimia nervosa (BN) and 26 binge eating disorder (BED). Length of illness was on average 7-8 years for people with anorexia and bulimia nervosa, and more than 20 years for binge eating disorders (Table 1). Seven patients with BED and one patient with BN had impaired fasting glucose (6.1-6.9 mmol/dl), and one patient with BED had type 2 diabetes (in total, 30.7% with BED had impaired glucose tolerance or type 2 diabetes).

[Table 1 about here]

[Table 2 about here]

Table 2 shows the percentage of patients missing food at mealtimes in each diagnostic group, and the percentage of NOVA-4 food consumed at each meal. Although patients with anorexia nervosa reported consuming on average 55% NOVA-4 foods, as opposed to approximately 72% in BN and 69% in BED, the difference was not statistically significant (Chi Square test, P=0.19). Reports of food intake pattern showed that lunch and evening meal were the most commonly consumed meals, whilst breakfast and snacks were often missed, suggesting that the main dietary intake shifted to the later part of the day. Bingeing was most common in the evening. During the day, most patients chose foods low in fat and protein. Diet products, such as artificially sweetened drinks and low fat products were common NOVA-4 choices , with no significant differences between the diagnostic groups (Chi-Square: P=0.43)

Patients binged 100% on NOVA-4 foods. Examples included: chocolate, ice-cream, crisps, sandwiches, biscuits, cakes, pizza, smoothies and donuts.

DISCUSSION

To our knowledge this is the first observational study exploring the frequency of NOVA-4 ultra-processed food choices of people with eating disorders. This was a retrospective casenote study using routine data. Both patients and clinicians were blind to the research hypothesis. Our main finding is patients (regardless of the type of eating disorder) binged on 100% of NOVA-4 foods. Binge foods were high in carbohydrate and fats. Meals were often missed during the day by all diagnostic groups, indicating that dietary restriction is shared between people with eating disorders. This is consistent with Fairburn's transdiagnostic model of eating disorders (Fairburn et al., 2015).

The link between obesity and NOVA-4 consumption has been shown in a number of studies, but to our knowledge, no study has examined the association with binge eating, or eating disorders (Juul et al., 2018; Mendonca et al., 2016).

NOVA-4 foods and binge eating

A recent carefully controlled randomized crossover trial on a metabolic ward (K. D. Hall et al., 2019) found that NOVA-4 foods resulted in overconsumption. Participants consumed an excess of 500kcal/day when they were placed on an ad libitum, ultra-processed diet, as compared with a minimally processed one by using a wide range of foods with similar appearance and similar macronutrient content. Participants did not report differences in palatability, suggesting that the increased food intake was driven by metabolic mechanisms. The hunger hormone ghrelin, fasting glucose and insulin levels were increased during the ultra-processed diet, whilst appetite-suppressing hormone peptide tyrosine tyrosine (PYY) reduced. The research team carefully tried to control macronutrient intake, but found that participants on ultra-processed diet increased both carbohydrate and fat intake, whilst protein intake remained the same. This is consistent with the protein leverage hypothesis, which suggests excess intake is driven by the dilution of dietary protein (Gosby, Conigrave, Raubenheimer, & Simpson, 2014; Martinez Steele, Raubenheimer, Simpson, Baraldi, & Monteiro, 2018).

A recent meta-analysis found that anorexia nervosa is associated with increased insulin sensitivity whilst bulimia nervosa and binge-eating disorders are associated with insulin resistance (Ilyas et al., 2018). Our findings are consistent with this, as 30% of patients with binge eating disorder had impaired glucose tolerance. This suggests that metabolic factors may contribute to binge eating. Furthermore, there is increasing recognition that there are significant individual differences in responses to common foods (Valdes, Walter, Segal, & Spector, 2018; Zeevi et al., 2015). This is partially driven by the microbiome, which is influenced by the diet (Rothschild et al., 2018). These findings may explain why some people develop certain metabolic or eating disorders in the modern food environment, while others do not.

Animal (DiFeliceantonio & Small, 2019) and human experiments (Small & DiFeliceantonio, 2019) have demonstrated that ultra-processed foods also alter the neurobiological reward pathways involved in eating behaviours. Neuroimaging studies have shown that food cues, which are predictive of calories, activate the striatum in humans. The magnitude of these responses is regulated by metabolic signals, and this process influences food intake according to energy requirement (DiFeliceantonio et al., 2018). However, non nutritive sweeteners, which are not found in nature, and combinations of sugars and fats (common in NOVA-4 products), disrupt the brain's ability accurately to estimate the energy value of foods and result in supra-additive effects, which may drive overconsumption (Small & DiFeliceantonio, 2019). Although these studies were carried out using only a small range of foods, these discoveries have important implications for our understanding of eating disorders. Small's group has developed a novel two stage model bringing together the biological and psycho-social factors influencing eating behaviours (Small & DiFeliceantonio, 2019). One system directly reflects the nutritional value of foods and relies on metabolic signals reaching the brain. This nutrient-sensing system plays a critical role in regulating striatal dopamine and reward. The second, conscious system influences food choices based on beliefs on healthfulness, cost, etc, which are heavily targeted by advertising and by the food environment. Patients with eating disorders choose diet products (which are commonly NOVA-4), believing them to be healthier options, unaware of the metabolic and neurobiological effects that impair accurate sensing of nutrient content by the brain and result in uncontrollable eating during a binge episode.

As this was a pilot observational study, there are limitations. We used routinely collected data, rather than the standard food frequency questionnaires. However, food frequency questionnaires have been heavily criticized, due to recall and reporting bias (Archer, Marlow, & Lavie, 2018). For example, the UK NDNS survey (Rauber et al., 2018) reported daily intake of only 1764.7 Kcal, which was inconsistent with the obesity epidemic, and therefore indicates significant underreporting, To improve the reliability and accuracy of self reports, in our study, we only attempted to code the type of foods and not the amounts consumed, and we did not attempt to estimate the overall calorie intake.

Recommendations for future research:

The links between and metabolic responses to ultra-processed foods and eating disorder behaviours should be an area for future study. New methodologies, such as using online data collection (Wark et al., 2018) or smart phone applications (Eldridge et al., 2018), would be helpful for exploring the links between the type of foods consumed and disordered eating in more detail and accuracy.

The concept of personalized nutritional approach, introduced by Segal's group (Zeevi et al., 2015), includes investigation of metabolic responses, such as glucose, insulin, lipids and changes in microbiome (Toribio-Mateas & Spector, 2017) and use continuous glucose monitoring to help people with metabolic diseases. This approach is also likely to be beneficial for people with eating disorders. The effectiveness of psychological treatment could be improved by including a personalized plan which eliminates ultra-processed foods. Modern technology, such as continuous glucose monitoring, could provide immediate and personalized feedback to the patient about the metabolic effects of foods, facilitating rapid behavioural change. This can be incorporated into psychological treatment, or even be used for remote monitoring, and can revolutionize treatment. This would be a particularly helpful approach for people with impaired glucose tolerance, which is a significant proportion of patients with binge eating.

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Table 1 Demographic and clinical features of the sample

	age ±SD	Age of onset±SD	BMI ±SD	EDE-Q ±SD
AN	24.7±8.6	16.9±3.6	15.4±3.8	1.2±1.9
BN	26.9±7.1	19.4±6.1	24.1±4.3	0.8±2.7
BED	39.0±10.8	16.6±8.4	38.3±3.8	0.7±8.0

Table 2 Dietary intake patterns

	AN		BN		BED	
	Meal missed (% patients)	NOVA-4 (% frequency of foods eaten)	Meal missed (% patients)	NOVA-4 (% frequency of foods eaten)	Meal missed (% patients)	NOVA-4 (% frequency of foods eaten)
Breakfast	10	55	47	76	30	57
Morning snack	59	33	56	73	60	70
Lunch	14	60	12	68	20	80
Afternoon snack	48	82	44	64	46	50
Dinner	9	44	16	48	4	56
Evening snack	73	67	87	100	59	100
Average daily intake		55		72		69

Common NOVA-4 food examples**: Breakfast:** Cereals, diet yogurt, soya milk/yogurt, diet drinks; **morning snack:** biscuits, snack bar, cake, diet drinks; **lunch:** sandwich, quorn sausages, waffle, cereal bar; **afternoon snack:** snack bar, biscuits, crisps, protein ball, diet drinks; **dinner:** ready meals, takeaway pizza, quorn pie; **evening snack:** biscuits, crisp, cakes, ice cream; **binge foods:** biscuits, chocolate, ice cream, crisps, cake, donuts, takeaway pizza